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(54) Waveguide microwave filter

(57) Microwave filter composed by resonant cavities (CAV) in a rectangular waveguide preferably formed by two bodies (3,4) in which these cavities (CAV) are coupled by means of rectangular windows perpendicular to the direction of propagation in the waveguide.

The filter has the corners of the cavities (CAV) rounded where their direction is parallel to that of the electric field inside the waveguide. This permits the filter to be machined much more easily, lowers manufacturing costs and requires less precision.

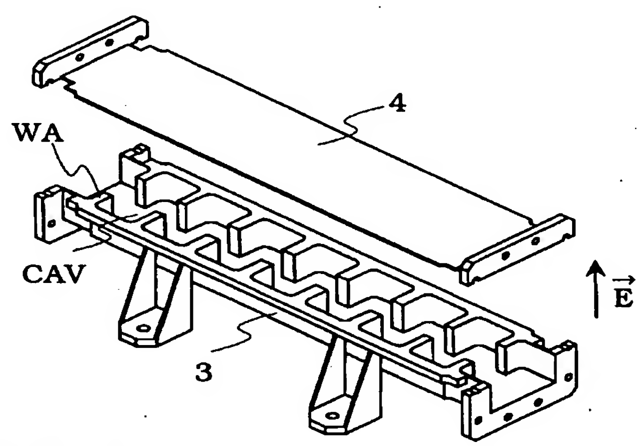

FIG. 3

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Description

OBJECT OF THE INVENTION

This invention concerns a microwave bandpass filter formed by a set of resonant cavities made from a waveguide, in which conductive walls are arranged perpendicular to the direction of propagation with a spacing between consecutive walls of one half wavelength. The electromagnetic coupling between two adjacent cavities is achieved by means of rectangular windows made in these conductive walls in the direction of the electric field.

The object of this invention is to develop a high-precision filter of the type mentioned above with low manufacturing cost, and which also offers high reliability and low manufacturing tolerances.

BACKGROUND OF THE INVENTION

Although the theory of this type of filter is well known to skill people in this field of technology, its implementation gives rise to a multitude of alternatives which offer determined characteristics in accordance with the manufacturing processes required and which are mainly determined by the physical structure of the filter in question.

To design the cavities that constitute the filter and decide the position and size of the windows that provide communication between the cavities, computer simulation techniques are employed based on their electrical characteristics. In this way, and based on the physical shape of the filter and in the theoretical models, these electrical characteristics can be reliably obtained.

To model the field distributions in a trustworthy manner, the cavities must have a perfectly regular geometrical shape; if not, it would be necessary to take into account effects that are difficult to model and which would lead to the filter characteristics not corresponding to reality in a sufficiently exact manner.

One way to construct a cavity filter in a waveguide of this type is described in the French patent FR 8912408 in which in a segment of a rectangular waveguide a series of slots are formed that are perpendicular to the direction of propagation of the waves, into which are inserted a number of flat conductive planes in order to constitute the pertinent cavities, leaving a small window for coupling between them.

With this procedure a basic filter can be obtained cheaply but precision is poor and, in addition, it requires a process for soldering the plates to the guide in the corresponding slots that is also fairly delicate; as a result, additional tuning elements are required that significantly increase the total cost of the filter (direct costs and costs related to adjustment times). In addition, in the case of filters mounted on board communications satellites, the additional weight is another very important factor to be borne in mind.

A first solution put into practice consists in making a very accurate design that does not required tuning elements, by means of the use of cavities that have a perfectly rectangular cross-section, easy to simulate in electromagnetic analysis, but which are very complicated to manufacture because of the need to make shapes with "live" edges at those corners that are not parallel to the electric field.

These cavities are formed by the internal milling of two symmetrical rectangular tubes, as is shown in figure 1, that permits the formation of right angles in the cavities in a longitudinal section of the filter in the direction of the electric field. The windows to provide coupling between cavities are formed centrally in them.

Nevertheless, the manufacturing process is intrinsically expensive due to the mechanical form that the two parts that form the filter must have, as it is difficult to achieve, on one hand, perfect symmetry between the two parts and, on the other hand, "live" corners when they are perpendicular to the surface area from which the excess material is being removed during the milling process.

CHARACTERISATION OF THE INVENTION

The problems mentioned are resolved according to the invention, in which the microwave filter composed by resonant cavities in a rectangular waveguide preferably formed by two bodies, and in which these cavities are coupled by means of rectangular windows perpendicular to the direction of propagation of the electromagnetic field, is characterised in that the rectangular windows for coupling between cavities are made according to the direction of the electric field of the waveguide.

Moreover, the corners of the cavities that are parallel to the electric field are rounded, which permits simpler, faster and less costly machining of the filter.

In this way, the filter in question proves simpler to make and consequently has manufacturing costs much lower than filters made according to the state of the art. In addition, it is also much less sensitive to manufacturing tolerance whereby the need for additional tuning elements disappears in the majority of applications.

BRIEF FOOTNOTES TO THE FIGURES

A fuller explanation of the invention can be obtained from the following description of a preferred implementation based on the figures attached, in which:

- figure 1 is a waveguide cavity bandpass filter in accordance with the state of the art,
- figure 2 is a longitudinal cross-section perpendicular to the electric field of the filter of figure 1,
- figure 3 is a waveguide cavity bandpass filter in accordance with the invention, and
- figure 4 shows a longitudinal cross-section perpendicular to the electric field of the filter of figure 3.

DESCRIPTION OF ONE WAY OF IMPLEMENTING THE INVENTION

As indicated above, the filter of figure 1 is an implementation of a waveguide cavity bandpass filter. The theory of this type of microwave filter establishes certain procedures for the analysis and simulation of the distribution of electromagnetic fields in the interior of cavities with a given geometry.

This analysis is a faithful reproduction when the geometrical shape of the cavities in question is perfectly regular and satisfies certain conditions. Thus, the electrical characteristics of the resulting filter, except for manufacturing tolerances, is perfectly predictable within a remarkably small margin of error.

In some applications prediction of the response in a very precise form is not of great importance since tuning elements can normally be incorporated (usually screws that are partially inserted into the cavity in order to modify the distribution of fields) and the electrical characteristics of the filter adjusted by trial and error.

This, although it represents a reduction in design cost, also represents an increase in total cost due to the need to include additional elements and the time to adjust the filter; in addition, it means extra weight which, though not normally representing a significant drawback, in the case of filters located on board communications satellites, does mean a major cost to be taken into consideration, as well as the impossibility of readjusting the filter once the satellite has been launched. For this reason, there is a requirement to design filters that need no tuning adjustments, like that shown in figure 1. To achieve this the true dismensions of the cavities and of the coupling windows have to be designed very exactly.

This filter is formed from a segment of waveguide consisting of two symmetrical bodies 1 and 2, joined longitudinally and screwed into position, which hold a number of cavities CAV of length $\lambda/2$ and rectangular cross-section, as is shown in figure 2.

Each cavity CAV is defined by the walls of the waveguide itself and by two transversal walls WA separated one from another by one half wavelength of the filter's centre frequency ($\lambda/2$).

To achieve the electromagnetic coupling between the cavities CAV, there is a window centrally located in the transversal walls WA, the height of which is the lesser of the dimensions of the transversal cross-section of the waveguide and the width of which depends on the degree of coupling between cavities CAV that is determined by the design of the filter in question.

To construct this filter mechanically, the starting point is two solid rectangular tubes from which, by milling or electro-etching, material is removed until the shape of the symmetrical bodies 1 and 2 is achieved, as is shown in figure 1. In this filter, in which the direction of the electric field is vertical, all the corners perpendicular to this field are "live" since, otherwise, rounded corners would substantially alter the electrical characteristics of the filter. This effect would be more easily predictable if the rounded corners were parallel to the electric field.

A longitudinal section perpendicular to the electric field, as can be seen in figure 2, shows how the coupling windows between cavities are arranged centrally, as well as the corners parallel to the electric field.

Figure 3 shows the filter of the invention for a design with the same electrical characteristics as that just described. This filter is also formed by two bodies 3 and 4, but in this case milling is only done in one of them (lower body 3). The windows for coupling between cavities CAV are made perpendicular to the milled face and they are located centrally in the transversal walls WA that separate the different cavities CAV.

The process of removing the excess material from milling is relatively simple and rapid, since the actual geometry is easier to achieve than in the previous case. This is particularly due to the fact that the corners perpendicular to the milled face can be rounded in form since, in this case, as has already been remarked, these corners are situated parallel to the electric field and their effect is much less and, moreover, they can be easily expressed in a mathematical model as a function of the radius of curvature. This permits the precise design of the filter without any requirement for adjustments.

The other, upper, body of the filter 4, is a flat surface that requires no additional removal process as in the previous case, consequently the manufacturing cost is not increased. This upper body 4 is joined, in like fashion to the filter of figure 1, to the lower body 3, being held in position by screws to constitute the waveguide cavity bandpass filter of the invention.

Figure 4 shows a longitudinal cross-section of the filter perpendicular to the electric field, in which it can also be seen how the windows for coupling between cavities are arranged centrally in them, as well as the corners parallel to the electric field, formed by rounded corners. This effect has been assessed theoretically, and it has been shown that the filter response is the same as that of the rectangular cavity with a slight correction in cavity length which depends on the radius of curvature of said rounded corners.

Claims

1. **MICROWAVE FILTER** composed by resonant cavities (CAV) in a rectangular waveguide preferably formed by two bodies (3,4), in which these cavities (CAV) are coupled by means of rectangular windows perpendicular to the direction of propagation in the waveguide, characterised in that the cavities (CAV) have rounded those corners whose direction is parallel to the electric field inside the waveguide.

2. **MICROWAVE FILTER** according to claim 1, characterised in that one of the bodies that form this filter is a flat plane.

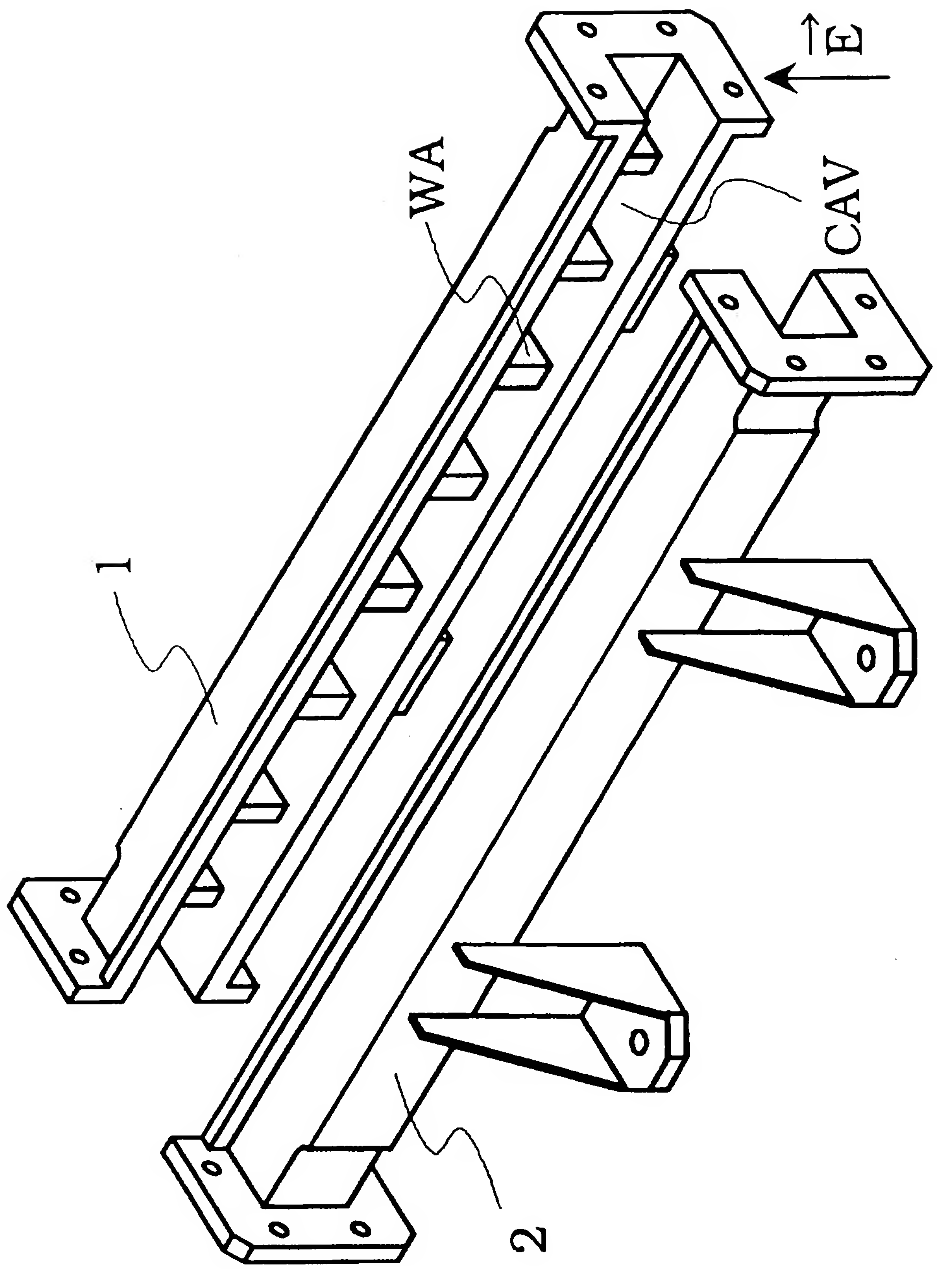

FIG. 1

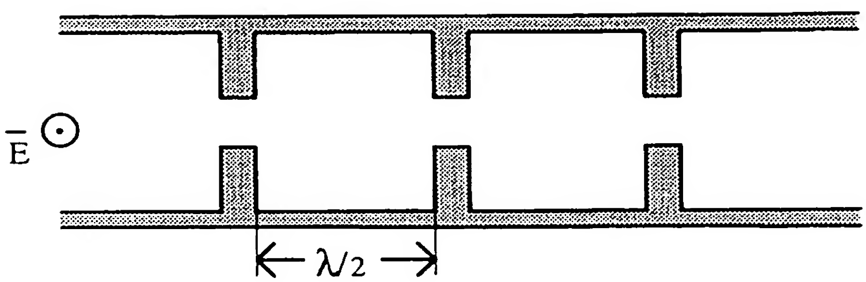

FIG. 2

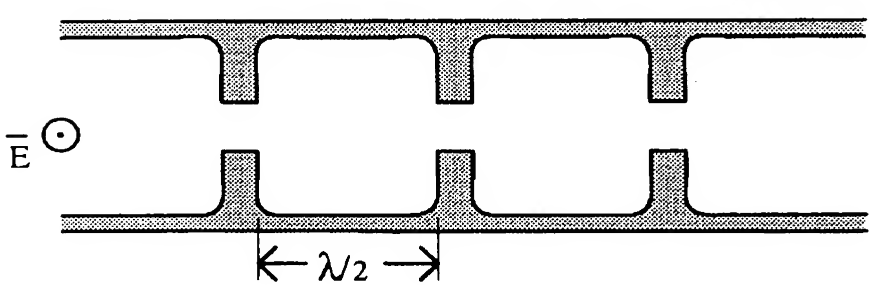

FIG. 4

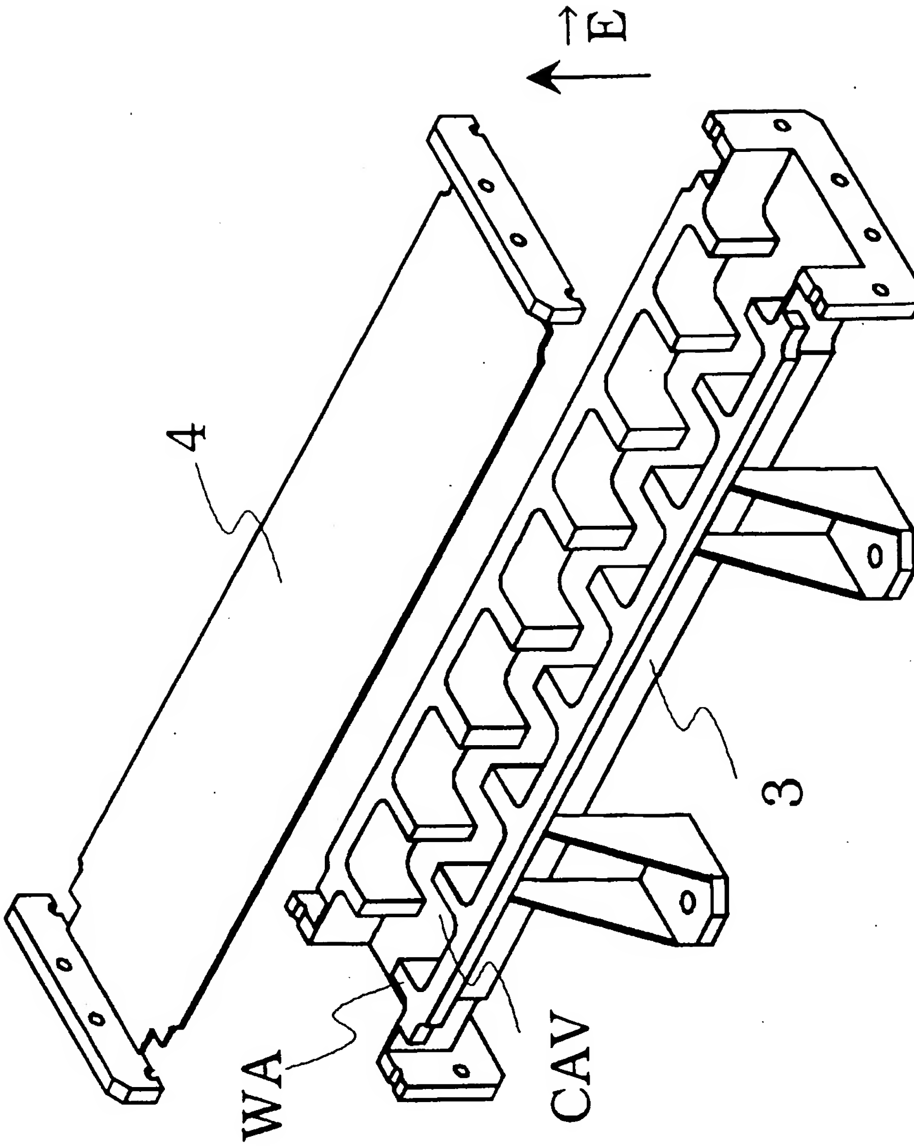

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 2459

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	FR-A-2 346 868 (COMPAGNIE INDUSTRIELLE DES TELECOMMUNICATIONS CIT-ALCATEL) * page 2, line 5 - page 3, line 29; figure 1 *	1,2	H01P1/208
X	US-A-3 137 828 (GERIG ET AL.) * the whole document *	1	
X	DE-A-36 35 499 (KATHREIN-WERKE KG) * the whole document *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 2, no. 3 (E-77) [9732] , 10 January 1978 & JP-A-52 117540 (MITSUBISHI DENKI K.K.), 3 October 1977, * abstract *	1	
A	US-A-4 745 617 (HARVEY) * column 10, line 34 - line 51; figure 15B *	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 April 1996	Den Otter, A

CATEGORY OF CITED DOCUMENTS

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